UNIVERSITI TEKNIKAL MALAYSIA MELAKA

SYNTHETIC HYBRID LAMINATE COMPOSITE USING POLYESTER VIA HAND LAY UP FOR HARDBOARD APPLICATION

This report submitted in accordance with requirement of the Universiti Teknikal Malaysia Melaka (UTeM) for the Bachelor Degree of Manufacturing Engineering (Engineering Materials)

By

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DECLARATION

I hereby, declared this report entitled "Synthetic Hybrid Laminate Composite Using Polyester via Hand Lay Up for Hardboard Application" is the results of my own research except as cited in references.

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APPROVAL

This report is submitted to the Faculty of Manufacturing Engineering of UTeM as a partial fulfillment of the requirements for the degree of Bachelor of Manufacturing Engineering (Engineering Materials) with Honors. The member of the supervisory committee is as follow:

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ABSTRAK

Dalam kajian ini, sifat mekanikal poliester dengan menggunakan kaedah *hand lay up* dalam hibrid laminat komposit telah dikaji bagi aplikasi papan keras. Bahan - bahan asas yang digunakan dalam kajian ini adalah poliester tak tepu, gentian kaca jenis E dan kawat besi. Penyelidikan ini telah dimulakan dengan mengkaji ciri dan sifat yang diperlukan untuk aplikasi papan keras. Penyelidikan ini juga bertujuan untuk menentukan sifat-sifat mekanikal dan fizikal berdasarkan jumlah lapisan dan jenis susunan gentian kaca bersama kawat besi yang berbeza dalam sistem laminat komposit. Tambahan lagi, nisbah yang paling optimum antara bahan pengikat dan bahan penguat dalam komposit telah dikaji. Melalui jumlah lapisan dan susunan dalam komposit laminat yang berbeza akan dibuat menggunakan kaedah *hand lay up*. Proses pengerasan untuk poliester akan dijalankan pada suhu bilik di bawah penekanan sejuk. Sebanyak sebelas jenis komposit laminat telah dihasilkan dan dipotong mengikut geometri khusus berdasarkan kepada piawaian ASTM untuk keperluan setiap ujian mekanikal. Penambahan kawat besi dan gentian kaca dalam komposit sintetik ini diharapkan dapat meningkatkan nilai daya impak, tarikan, lenturan, sifat kekerasan serta ketahanan terhadap air yang di uji dalam makmal. Daripada ujian, sampel yang paling optimum diamati dan dipilih. Berdasarkan analisis dari kedua-dua ujian mekanikal dan fizikal, didapati bahawa hibrid laminat komposit SN 9 dengan 7 gentian kaca di atas dan 3 lapis di bawah dari kawat besi diperkuatkan poliester memberikan nilai yang paling tinggi dari kekuatan tarikan dengan 198.21 MPa, kekuatan lenturan dengan 4.52 MPa, kekuatan impak dengan 208.20 kJ/m^2 dan sifat kekerasan dengan 87.2. Selain itu, pertahanan terhadap air dari hibrid laminat komposit ini adalah lebih baik. Sifat-sifat untuk sampel ini telah dibanding dengan produk sebernarnya iaitu palet plastik untuk mengantikannya dalam aplikasi papan keras. Sebagai hasilnya, sifat-sifat yang unggul adalah didapati dalam sampel ini sekiranya dibanding dengan produk sebenarnya.

ABSTRACT

In this study, the mechanical properties of polyester resins by hand lay up method in a hybrid laminate composite had been investigated for hardboard application. The raw materials used were unsaturated polyester, glass fiber type E and wire mesh. This research was started by the study of characterization and properties required for hardboard applications. Then, it was aimed to determine the properties of different layer and arrangement of glass fiber and wire mesh reinforcements in a laminate composite system. In addition, the most optimum ratio of matrix and reinforcement in the composite based on cost and properties was investigated. The different layers and arrangements in laminate composite were then fabricated by hand lay up method. The curing of polyester was done at room temperature under cold press. Eleven samples of laminate composite had been fabricated and cut into the specific dimensions accordingly to the ASTM standard for each mechanical testing. The enhancement of the tensile, flexural, impact, hardness properties as well as water resistance of the synthetic composites had been investigated by laboratory testing. From the testing, the most optimum sample were observed and selected. Based on the analysis of both mechanical and physical testing, it was found that the hybrid laminate composite of SN 9 with 7 fiberglass at top and 3 layers at bottom of the wire mesh reinforced polyester resin gave the highest value of tensile strength with 198.21 MPa, flexural strength with 4.52 MPa, impact strength with 208.20 kJ/m^2 and hardness with 87.2. Besides that, the water resistance of this hybrid laminate composite was better. The properties of this sample had been compared to the actual product that was plastic pallet in order to replace it in hardboard application. As a result, superior properties were found in the sample as compared to the actual product.

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DEDICATION

Dedicated to my beloved father, Khor Yak Tiang and mother, Chong Soon Mei for giving me financial and moral support.

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LIST OF SYMBOLS

%	-	Percent
°	-	Degree
±	-	Plus minus
° C	-	Degree Celcius
A	-	Area
cm	-	Centimeter
E	-	Tensile modulus
F	-	Force
g/mm^2	-	Gram per milimeter square
J	-	Joule
J/m^2	-	Joule per meter square
kN/min	-	Kilo Newton per minute
kg/m^3	-	Kilogram per meter cube
mm	-	Millimeter
mm/min	-	Milimeter per minute
MPa	-	Mega Pascal
N/m^2	-	Newton per meter square
V	-	Volume
ε	-	Tensile strain
σ	-	Tensile strength
F_{ar}	-	Fiber area
l	-	Length
d	-	Diameter
m	-	Meter
s	-	Second
RM	-	Ringgit Malaysia

LIST OF ABBREVIATIONS

AP	-	Actual Product
ASTM	-	American Standard Test Method
BOM	-	Bill of Material
C	-	Complete Break
CMC	-	Ceramic Matrix Composite
FRP	-	Fiber Reinforced Plastic
H	-	Hinge Break
HDPE	-	High Density Polyethylene
ISO	-	International Standard Organization
MEKP	-	Methyl Ethyl Ketone Peroxide
MMC	-	Metal Matrix Composite
NB	-	Non Break
P	-	Partial Break
PMC	-	Polymer Matrix Composite
RM	-	Ringgit Malaysia
ROM	-	Rule of Mixture
RTM	-	Resin Transfer Moulding
SME	-	Small Medium Enterprise
SMI	-	Small Medium Industry
SN	-	Serial Number
UTeM	-	Universiti Teknikal Malaysia Melaka
UTM	-	Universal Tensile Machine
UTS	-	Ultimate Tensile Strength
UV	-	Ultra Violet
VIP	-	Vacuum Infusion Process

CHAPTER 1
INTRODUCTION

1.1 Background

Hybrid composites are the composites that are produced by more than two of reinforcements or matrix materials. There are several types of hybrid composites characterized. One of the most common and simplest hybrid composites is interply or laminated, where alternate layers of the two or more materials are stacked in a regular manner.

Plastic laminates composite is normally meant Fiber Reinforced Plastic (FRP) which is the composite materials made of a polymer matrix reinforced with fibers. The most common used fiber is fiberglass, carbon, or aramid, while the matrix material is usually an epoxy, or polyester which is from family of thermosetting plastic. Glass reinforced plastic was the strongest and had the highest resistivity to deforming forces when force was applied on it in parallel. However, it became the weakest when the fibers were perpendicular (Morton, 1974, p. 3). To overcome the limitation of the fiber reinforced composite, the orientation of the glass fiber fabric were oriented in two dimensional weaves and above. When forces were applied perpendicularly to one orientation, another orientation in parallel overcame the forces accordingly by Erhard, (2006, p. 199). Hence, this eliminated the potential for weak spots in the polymer.

The most common used method for reinforced plastics composite products is hand lay-up process. It is due to its low cost and it can consist of any size or configuration. Moreover, the process does not require any special tools. Parts can be easily

fabricated in a short period. Besides that, molds can be easily modified, cut into part for prefabrication and applied to create various surface textures. The rigid properties of the final product require that under cuts and straight wall be eliminated. Any openings must be machined in post molding operations. All corners must have somewhat large radius.

Polyester resin is one of the most common used in hand lay-up method for FRP. It acts as the matrix in the composite. It is popular and widely used, especially in the marine industry to shape and form hulls and outer layers of ships. All polyester resins are pale in colors and thermosetting. Besides, polyester resins are resistant to water and UV rays.

Fiberglass is material made from extremely fine fibers of glass. It is normally used as a reinforcing agent for many polymer products. Glass fibers are popular due to their high ratio of surface area to weight which can produce very light products with high strengths. Besides fiberglass, reinforcing wire mesh can be the reinforcement in the polymer matrix composite. Wire mesh is used due to its unique deformed wire pattern which offers superior bonding, improved stress distribution and crack width control. Weldmesh is a welded steel mesh manufactured from bright drawn wire electrically welded at the intersections. The most common raw material of the steel mesh is stainless steel due to its properties. According to BRC West Indies Limited (2005, p. 2), weldmesh had average shear strength equal to 80 % of the wire strength.

Normally, hardboard was made out of exploded wood fibers that have been highly compressed in order to make it denser and much stronger and harder. Hence, hardboard was sometimes called high density fiberboard, which was stated by Frane (1994, p. 156). According to the Composite Panel Association, other materials could be added during the manufacturing process of hardboard to improve certain properties, such as resistance to abrasion and moisture, and increased strength and durability. Hardboard had a uniform thickness, density and appearance and had no grain. It resisted marring, scuffing and abrasion, as well as changes in temperature and humidity. Hardboard could be cut, routed, shaped and drilled with standard woodworking tools. In addition, hardboard could be securely glued or fastened with

screws, staples or nails. Hardboard panels could be laminated with paper overlays, plastic laminates and veneers.

1.2 Problem Statements

In the past, wood fiber was often used in hardboard application due to its inexpensive and fairly rigid product for its thickness, and yet it was flexible enough to bend where needed. However, it was not consistent in thickness because of the continuous press it was made in as it was opposite to the single opening press the wood fiber was made. Besides that, this type of hardboard could not be used outside because it absorbed water. Due to the limitation of the previous hardboard product, a thermosetting material, polyester which had good resistance in water and more strength and high dimensional stability was selected as replacements to vary the applications of hardboard.

Hardboard sheet was commonly formed in a hot press with the application of heat and pressure. However, the board produced harmful gases and vapors during the heat forming process. Also, this heat method was expensive and results in a long forming cycle time (Cole *et al.*, 1982, p. 2). In order to overcome the problems, hand lay-up method was carried out and the hydraulic cold press was applied to replace hot forming hardboard. Hand lay-up method was the chosen because it was simple, widely used and low cost. Furthermore, small thickness and high strength of hardboard were preferable. The hydraulic press was applied to compress it for improvements of the properties. Modern hydraulic presses were, in some cases, better suited to applications where the mechanical press had been traditionally more popular (Lown, 1999, p. 1). However, hydraulic press might cost less than an equivalent mechanical press depending on the application. Hydraulic cold press was simple process which was done at room temperature to offer good performance and reliability.

The quality of the product was very dependent on thickness and physical properties of the hardboard. Normally, composite was made from one matrix and reinforcement.

For example, polyester was the matrix while fiberglass acted as the reinforcement. However, this combination was not strong enough for some hardboard applications. Stronger and more stable product was always preferred. Thus, wire mesh was added as a support in order to compare the strength and stability. In this composite, polyester was matrix, fiberglass as reinforcement and wire mesh acted as the back bone of the hardboard.

1.3 Objectives

The objectives that were needed to achieve include:

(a) To produce laminate composite by hand lay-up method via polyester resins in order to compare the tensile, flexural, impact, hardness and water absorption properties.
(b) To determine the failure modes of different layer and arrangement of reinforcements in a laminate composite.
(c) To investigate on the most optimum ratio of matrix and reinforcement based on cost and properties in the laminate composite sample.

1.4 Scope of Study

(a) Study of requirements on hardboard applications.
(b) Study of fibreglass reinforced polyester laminated hardboard panels.
(c) Study of properties of polyester resins, fibreglass and reinforcing wire mesh in a hybrid laminate composite.
(d) Study of elastic constants of unidirectional and multidirectional composite.
(e) Study of composition between matrix and reinforcements in composites.